

# The Regional Dimension of the Distribution and Effects of Public Incentives Directed towards Innovation of Firms

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**ABSTRACT:** This study is based on the recent vision that the innovative activity is a territorial phenomenon which is enhanced by the cooperation between actors and local infrastructures. The aim of this study is to determine whether the specific economic and institutional conditions of a region have an influence on the results of a national policy intended to support entrepreneurial innovation. The analysis is directed towards comparing the effect of this policy between firms located in Madrid, Catalonia and the Basque country, regions which concentrate around 70% of Spain's innovative activity. The type of analysis undertaken allows to approach a situation which lies close to solving two of the most important methodological problems which arise when the evaluation of innovation policies is put into practice: the lack of control over the aid distribution process, and the non-estimation of a counterfactual state (the scenario without public support). The results of this study allow to conclude that the region plays an important differentiating role in the final result of the national innovation policy. Therefore, this study recommends to include the localization of the firm in future evaluations.

**KEYWORDS:** R&D, R&D Subsidies, Innovation Policy, Propensity Score Matching

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## 1. INTRODUCTION

Throughout the last two decades special interest has been paid to the study of the factors that determine the geographical location of innovative business operations. Such attention has cropped up as a result of the appearance of industrial clusters and competitive trade regions that have given birth to the notion that innovative activity is a partially territorial phenomenon, boosted by the cooperation between local actors and the difficulty to transfer specific resources (Cooke et al., 2000; Tödting and Kaufman, 2001; Asheim et al., 2003). This idea is supported by abundant empirical evidence which reveals that the factors identified by the theory as relevant for technological change to take place, such as, the infrastructures, the nature of relations between businesses, learning ability and innovative activity, significantly differ from one region to another (Oughton et al. 2002).

The acceptance of such ideas caused a strong impact on innovation policies. The combination of the regional level and the characteristics of the firms is becoming the basis on which the design of the political intervention is funded (Nauwelaers and Wintjes, 2002). Some programmes which have been launched in Europe kept in mind the regional level<sup>1</sup> and some national governments have started to adapt their policies to local requirements (Clarysse and Muldur, 2001). Such actions have many advantages: regions that have developed the appropriate administrative mechanisms to support the entrepreneurial innovation, eventually develop into regions of economic interest which take advantage of the links and synergies among their local actors (Cook, 2003).

In this context, national policy remains a protagonist. In many industrialised countries innovation policies are formulated by the central government. However, regional differences regarding innovative activity reveal according to Holbrook and Salazar (2003), that the national policy does not affect all regions in equal terms. Given that economic convergence of regions with different levels of technological development is not easy (Clarysse and Muldur, 2001), for some authors a successful national innovation policy should be focussed on the regional dimension as the key aspect in the process of technological change (Storper, 1995; Scott, 1996; Cooke et al., 1997; Dohse, 2000).

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<sup>1</sup> Examples of such programmes are the RITTS (Regional Innovation Infrastructures and Technology Transfer Strategies) and the RTP (Regional Technology Plans).

Although there are practically no comparative studies on the effect of national innovation policies in a regional context, there is no doubt that the existence of differences offers a great opportunity to justify changes in the distribution of such policies. Therefore, the regional dimension becomes a key factor in the evaluation of national innovation policies.

This work offers for the first time an empirical evidence that should allow to determine if the specific economic and institutional conditions of a region have an influence on the results of a national policy intended to support the entrepreneurial innovation. This study assesses the distribution and the effect of the national subsidies to innovation on the firms' R&D intensity (Total R&D expenditures/Sales\*100) of firms located in different regions. Concretely, firms located in the autonomous regions of Catalonia, Madrid and the Basque Country, regions which concentrate 70.5% of the innovative activity of Spanish firms (COTEC, 2003).

The analysis of both the distribution and the effect was undertaken by means of a method based on the assessment of non-experimental treatments, Propensity Score Matching (PSM), recently applied in the evaluation of political interventions. The PSM helps to a certain extent to deal with two significant aspects of the evaluation process: the control over the process of subsidy distribution and the estimation of a counterfactual state. Concern about such aspects is derived from the recent attention shown in the literature with regard to specific problems faced by policy evaluation, namely, sample selection bias and endogeneity. It is a well known fact, that the aid distribution is a non random process. The participation of firms in aid programmes is determined by Government's decision to concede the support and, implicitly, by the decision of firms to participate. This converts public financing in an endogenous variable which must be explained. Therefore, its inclusion within a regression model could cause inconsistent estimates (Busom, 2000). In addition, there could also exist a distortion in the selection process derived either from the government pressure to support successful firms or from the ability developed by some firms to capture a large number of grants (Lerner, 1999; Wallsten, 2000; Heijs, 2003).

In general, empirical studies that deal with the effect of subsidies in relation to the innovative effort of firms are using regression models. Based on such models, a positive correlation between subsidies and firms' R&D may be established. However, Wallsten (2000) points out that it is impossible to determine whether subsidies induce more R&D expense, or whether the firms that invest more in R&D are those that are receiving the subsidies. This emphasises that it is not only necessary to control the problem of endogeneity,

but also that the effect of the subsidy policy must be isolated from other possible causes that could explain an autonomous evolution of such investment or innovative effort (Arvanitis, 2002). Notwithstanding the method used, researchers agree that the estimation of the “causal” effect of subsidies on innovation, requires comparing the effect of the policy with the situation in absence of such a policy (Papaconstantinou and Polt, 1997). Therefore, this situation or counterfactual state should be estimated.

The PSM allows to obtain non biased estimations of a causal effect by comparing the target variable (in this case R&D Intensity) of the units exposed to a treatment or *factual* state with the units not exposed to a treatment or *counterfactual* state. The PSM has recently been applied to the evaluation of the innovation policy in the German and in the French case (Czarnitzki and Fier, 2002; Almus and Czarnitzki, 2003; Duguet, 2003). In contrast to other studies, this analysis includes aspects that have never been considered previously in the literature on policy evaluation. Such aspects are related to the strategic activity of firms, their investment capacity, their difficulty to obtain innovation resources and the market conditions in which they operate. The wide selection of variables of this study could contribute to a better understanding of the factors which influence the distribution of aid and their possible relationship with the final outcome of the policy.

This study is structured as follows: the second section describes the methodology, the data and the variables. A discussion concerning the results of the empirical analysis is presented in the third section. And finally, section four offers the conclusions drawn.

## **2. METHODOLOGY, DATA AND VARIABLES**

### **2.1 Methodology**

Following the work of Rosenbaum and Rubin (1983), the method of Propensity Score Matching has been widely used in the evaluation of political interventions, especially those concerning the labour market (Lechner, 1999; Heckman et al.; 1999; Dehejia and Wahbam, 2002). By means of the PSM it is possible to identify the causal effect of a binary treatment (T). In studies where the assignment of units to a treatment is non random, the PSM allows to make non biased estimations of  $(\tau)$  – the average treatment effect on the treated (ATT), by comparing the result variable (Y) of the units exposed to a treatment or factual

state ( $Y_1$ ) with the units not exposed to a treatment or counterfactual state ( $Y_0$ ). Thus  $\tau$  is defined as:

$$E(\tau) = E(Y_{1i} | T_i = 1) - E(Y_{0i} | T_i = 1) \quad [1]$$

Because a unit ( $i$ ) cannot simultaneously be observed in both states, the counterfactual state is estimated by means of a control group. The PSM is used in this study to estimate the average effect of innovation subsidies (T) on the firms' R&D intensity (Y).

The PMS is especially useful in non-experimental studies where the treated units differ systematically from the units of the control group (a problem known in econometric literature as sample selection bias). The PMS reduces bias by means of a matching method that compares units exposed to the treatment with units of the control group which are similar in terms of their observable characteristics. Due to the fact that the matching of units of many characteristics  $n$  in a  $n$ -dimensional vector is generally unfeasible, the method reduces the pre-treatment characteristics of each unit into a scalar variable or propensity score (PS) in order to make matching more feasible<sup>2</sup>. The PS is defined as the conditional probability of receiving a treatment given a group of individual pre-treatment characteristics ( $X_i$ ). The Appendix gives details on the equation to estimate the PS.

In this work the PS is defined as the conditional probability of receiving innovation subsidies. Therefore, the matching is made among firms that receive innovation subsidies with firms that do not receive subsidies, but have the same propensity of obtaining them (control group).

Since it is hardly likely to find two units with the same PS value, it is appropriate to use a matching method. This analysis uses the nearest neighbour matching to select for each treated unit a control group unit which has the closest propensity score. Finally, the estimation of the causal effect requires compliance of a series of assumptions to ensure that the assignment to the treatment is random and that the counterfactual state is estimated in basis of the control group. The counterfactual state of the control group must be the closest for subsidised firms in the case of not receiving aid (See the Appendix).

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<sup>2</sup> In other words, by using the PS as a matching criterion, the dimensionality problem of the high number of observable characteristics is reduced.

Once these assumptions are complied, if  $T$  takes the value of 1 when a firm ( $i$ ) receives a subsidy and 0 in the opposite case, and  $p(X_i)$  represents the propensity score, then the ATT ( $\tau$ ) may be estimated as follows:

$$\tau = E\{E\{Y_{1i} | T_i = 1, p(X_i)\} - E\{Y_{0i} | T_i = 0, p(X_i)\} | T_i = 1\} \quad [2]$$

Once the observable differences between the two groups are controlled, the only remaining difference is allocated to the treatment effect of the subsidies. The ATT may be estimated by taking the average differences. The Appendix gives details to derive the ATT.

## 2.2 Data

The data used in this study proceeds from the survey on Business Strategies (Encuesta sobre Estrategias Empresariales / ESEE) prepared by the Foundation SEPI. We have used data of firms during the period spanning from 1998 to 2000. The sample was limited to the innovative firms which answered the questionnaire during the three consecutive years, and in addition, invested in R&D during that period. The sample includes firms that received national subsidies for innovation, excluding regional or European grants. The sample contains a total of 1499 Spanish firms distributed as follows: 340 in Catalonia, 298 in Madrid, 105 in the Basque Country and 756 in other regions.

## 2.3 Variables used to estimate the propensity score

As explained above in the methodology, the estimation of the propensity score (in other words, the conditional probability of receiving subsidies for innovation) is a preliminary step necessary to estimate the causal effect. Up to the present time, the selection of variables which explain the conditional probability has been approached intuitively in the literature, and has only responded to the necessity to include equations in the models in order to reduce the bias derived from a non random aid distribution. Studies directed towards analysing the aid distribution problem and the characteristics of the subsidised firms are practically non existing. Of the literature up to the present, we only know of two: Fernández et al., (1996) and Blanes and Busom (2004).

A pending task of evaluation studies is the construction of a general model which explains the participation of firms in support programmes. Although this study does not intend to derive such a model, following the related empirical evidence (Fernández et al., 1996; Lerner, 1999; Heijs, 1999, 2001; Busom,

2000; Wallsten, 2000; Acosta and Modrego, 2001; Arvanitis et al., 2002; Czarnitzki and Fier, 2002; Almus and Czarnitzki, 2003; Duguet, 2003), a set of variables has been selected in this study in order to estimate the conditional probability of obtaining subsidies<sup>3</sup>. Additionally, considering that the methodology allows, variables which had not been previously analysed in the literature have been included in this study to offer information about the innovation policy approach and direction. These variables are related to: the ability to obtain resources, the possibility of a privileged relationship with agencies, the innovation strategy and the degree of technological dependence of the firm. Although most of the previous analysis have not presented any formal hypothesis, in this study each variable was associated to an assumption in order to test whether it positively or negatively influenced on the probability of obtaining innovation subsidies. In this context, three groups of variables were identified:

### *Variables associated with the firms' characteristics*

*Size* was included (log of the number of employees) and *age* (average age during the period) as indicators of experience, management capabilities and ability to obtain resources (Arvanitis et al., 2002; Czarnitzki and Fier, 2002; Almus and Czarnitzki, 2003). In order to control for industrial differences, the firms were classified as belonging to *high, medium or low tech industries*<sup>4</sup>.

The *firm ownership* (percentage of capital participation) was included with the purpose to test whether the aid was mainly addressed to firms with foreign or public capital participation (Busom, 2000; Arvanitis et al., 2002; Almus and Czarnitzki, 2003)<sup>5</sup>. The subsidiaries of foreign companies usually see their R&D strategy influenced (Vaugelers, 1997) and could take advantage of the technological developments in other countries (Busom, 2003). Due to the aforementioned reason, agencies are expected to discriminate against these kinds of firms. The public share is included in order to test for a possible privileged relationship with government agencies. Following the study of Lichtenberg (1987), we have included for the same reason, a variable that indicates whether the *government is a customer* of the subsidised firm.

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<sup>3</sup> All these studies have included equations in their models to explain the participation of firms in support programmes, however, it should be noted that the objective of these studies was not the analysis of the aid distribution problem in itself.

<sup>4</sup> The high tech industry was maintained as a reference.

<sup>5</sup> The general tendency of these studies is a stricter selection of firms with government capital and a smaller share of companies with foreign capital.

Finally, we have included a variable which intends to detect possible deviations in the distribution of subsidies: the *difficulty in funding innovation activity*. Instruments such as subsidies are expected to be directed towards firms for whom financing is a barrier to innovation (Arvanitis et al., 2002). Firms who can develop their innovation activity in the same manner as if they had not received subsidies, should not be the target of aid. The variable acquires a value of 1 if the company had difficulties to obtain external funding for innovation, and 0 in the opposite case.

### ***Market related variables***

The selection of this group of variables responds to the necessity to keep in mind, within the framework of innovation policy evaluation models, the competitive environment in which the firms operate (Papaconstantinou and Polt, 1997). A dichotomised variable was included to reveal whether the firm was operating within an expanding market during the period of analysis. Similar to other studies, we have included the *export propensity* (average of exports/average of sales \* 100) within this group of variables, as a measure of foreign competitiveness (Fernández et al. 1996; Busom, 2000; Almus and Czarnitzki, 2003).

### ***Technological indicators***

Indicators have been introduced to test whether firms having a formal and articulated innovation activity are those that mainly obtain subsidies. Two dichotomised variables indicate whether the firm has *innovation planning and management activities* and holds *technological cooperation agreements*. With regard to the first variable, firms that plan their operations systematically and detail them in a plan, should be expected to find it easier to file aid applications (Heijs, 2001). This variable, to a certain extent, is also a representative of the absorption capacity, and therefore, it is interesting to find out whether it increases the probability to obtain subsidies. The technological cooperation indicator was included in order to examine whether companies with a certain potential for technology transfer find it easier to access support programmes. For the same reason, we have also included the variable *technological exports*<sup>6</sup>. Differing from other studies, it seems important to include the variable *technological imports* as an indicator of technical dependence, as it is possible to deem that one of the targets of the policy is to reduce the dependence while favouring the internal production of innovations.

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<sup>6</sup> The variables related to the export and import of technology take value of 1 if the firm made or received payments for foreign technical assistance.



In a great majority of the policy evaluation studies, the previous R&D experience proved to be one of the main explicatory variables of the firms' participation in aid programmes (Busom, 2000; Acosta and Modrego, 2001; Czarnizki and Fier, 2003). In general terms, studies usually consider data regarding R&D expenditures of the previous year in which aid was granted or the number of employees involved in R&D. These variables are included in order to test whether agencies select firms that have a certain innovation experience and could, presumably, ensure the success of the subsidy projects. This study includes the number of patents recorded during the preceding year in which the aid was granted.

### **3. RESULTS OF THE EMPIRICAL ANALYSIS AND DISCUSSION**

In the present study we distinguish between the two types of analyses undertaken, namely, the estimation of the propensity score and the estimation of the causal effect of the policy. Albeit the fact that the former is a preliminary step of the methodology, since all the variables related to the individual characteristics are reduced to a scalar variable, or propensity score (PS); we detail the PS estimation with the objective to gain a deeper knowledge of the variables that influence the subsidy distribution process in Spain and their possible relationship with the final outcome of the innovation policy. In addition, because the analyses are made using data from different regions, the study allows us to examine whether there exist differences between firms subsidised in a certain region compared to those subsidised in other regions.

#### **3.1 Factors that influence on the propensity to obtain innovation subsidies.**

A logit model was used in the present study to estimate the propensity of firms to obtain innovation subsidies (Table 1). At the national level, the main beneficiaries of the subsidies are: big firms with Spanish capital, exporters, present in expanding markets and having formal and articulated innovation activities. These results are in accordance to some obtained previously by the related empirical evidence (Fernández et al., 1996; Lerner, 1999; Heijts, 1999, 2000; Busom, 2000; Wallsten, 2000; Acosta and Modrego, 2001; Czarnitzki and Fier, 2002; Almus and Czarnitzki, 2003; Blanes and Busom, 2004). At continuation follows a detailed summary of the results obtained from the regional analysis:

- Size always had a positive and significant influence.

- Low and medium tech industries had reduced probabilities of obtaining innovation aid, except in the case of Catalonia; i.e., in this autonomous region presumably companies belonging to any industry could probably obtain innovation aid.
- In the case of the autonomous region of Madrid, having the central Government as a client of the firm significantly increased the probability of obtaining innovation subsidies.
- In all cases, planning and managing of R&D activities had a positive and significant influence in order to obtain public support.
- Technological cooperation was significant in the case of the autonomous region Catalonia.
- The innovative experience significantly influenced in the autonomous region of Madrid.
- Technological export had a positive and significant influence in all three regions.

In general, we may conclude that notwithstanding the autonomous region involved, the Spanish firms of the manufacturing industry which have the highest probabilities of obtaining innovation aid are: the big firms that manage and plan their R&D activities. Nevertheless, regional differences were detected while applying for Government aid. For instance, in the case of the autonomous regions of Catalonia and Madrid, application for subsidies is usually more strict and several aspects influence, such as: the foreign capital participation, the market, whether the Government is a customer of the firm, the technological cooperation and the previous R&D experience of the firm. Stated in another way, we could say that in the autonomous regions of Catalonia and Madrid the subsidies are granted to firms that are able to warrant the technical and financial feasibility of the projects. On the contrary, the opposite case was found in the Basque Country where most technological indicators did not appear to have a significant influence.

### **3.2. Effect of the innovation policy on the firms' R&D intensity.**

Having discussed and controlled the observable differences between the two groups of firms, the average effect of the innovation policy on the subsidised firms' innovative activities is summarised in Table 2.

According to the general model, Spanish subsidised firms are on average 1.84% more intensive in R&D activities than the group of non subsidised firms. The

effect of the support instruments granted by the central Government was significant and positive in all cases. Despite the fact that aid on average did not significantly increase the innovative effort, it is important to stress the absence of a “crowding out effect” of public funding with regard to private funding. In other words, firms are not generally substituting their private efforts for public effort. However, this study has revealed regional differences as far as the effect of the national innovation policy is concerned. The autonomous regions of Catalonia and the Basque Country showed the highest effect regarding national innovation subsidies, exceeding the Spanish average or general model (2.50% and 2.31%, respectively). On the other hand, the autonomous region of Madrid attained an effect (1.44%) below the Spanish average.

All of the above allows us to conclude that the region causes a differentiating effect concerning the final outcome of the innovation policy, and therefore, it will be necessary to keep in mind the localisation of the firm when policy effects are estimated. Although in the present study the subsidy distribution process has been controlled, it is possible to conclude that there are three significant elements which characterised the regions with a higher policy effect (facing the rest of the regions): the firms’ location, firms operating in expanding markets, and finally, firms exporting technology.

#### **4. CONCLUSIONS**

The purpose of this study was to analyse whether regional differences exist in relation to the factors that bear an influence on the firms’ chances of obtaining national innovation subsidies, as well as, on the effect of such a policy. The study included the autonomous regions of Madrid, Catalonia and the Basque Country, together with the rest of the regions within Spain. The statistical analysis was undertaken using the non-parametric approach of Propensity Score Matching (PSM). This method allows to take into account two key aspects related to the evaluation of innovation policies, explicitly, the process of aid distribution and the estimation of the counterfactual state.

The first part of the present analysis, addressed to investigate and control the process of aid distribution, allowed us to conclude that, in general terms, the big Spanish firms which plan and manage their R&D activities are the main beneficiaries of the subsidies. Nonetheless, regional differences were detected with regard to the distribution of the public aid. For instance, in the autonomous

regions of Catalonia and Madrid, public aid is mainly granted to firms that are able to ensure the technical and financial feasibility of their projects. Technological indicators were determinant in these regions. On the contrary, the difficulty in funding innovation activity was not significant. A remarkable conclusion is that one of the subsidy targets is to assist firms for whom funding is a barrier to undertake innovation. The subsidy distribution in these regions is clearly focused on the outcome of results, denominated in the literature as "picking the winners". As far as the Basque Country is concerned, firms that resorted to this kind of aid showed less strict characteristics, since the number of variables that influenced on the probability of obtaining aid was smaller and no determinant aspects relative to the innovative experience or technological cooperation were detected.

Respect to the policy effect, significant regional differences were identified. The autonomous regions of Catalonia and the Basque Country reached an average effect well above the Spanish average, while the autonomous region of Madrid did not manage to exceed the Spanish average. This study has recognised that there exist three significant variables which characterised the regions with a higher policy effect (compared to the rest of the regions): the firms' location, firms operating in expanding markets, and last, firms exporting technology.

The findings of this study allow to conclude that the region produces a differentiating effect with regard to the distribution and effect of the national innovation policy. Even though the purpose of this study was not to seek the regional elements that produce such differences, the current analysis clearly states that it is necessary to consider the location of firms in order to correctly assess the effect of innovation policies.

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**TABLE 1**  
**RESULTS OF THE LOGIT ESTIMATE**

Variables	Spain	Sig	Catalonia	Sig	Madrid	Sig	Basque Country	Sig
Size	0,571	***	0,573	***	0,676	**	1,143	**
Medium technology industry	-0,558	**	-0,638		-0,674		-1,054	
Low technology industry	-0,469	**	0,206		-1,452	*	-2,099	*
Age	-0,206	*	0,083		-0,469		-0,689	
Foreign capital %	-0,08	***	-0,009	*	0,000		-0,005	
Government capital %	0,016	**	ND	ND	0,207		0,051	
Government is a firm's client	0,188		-0,373		1,262	**	2,097	
Export propensity	0,007	**	0,003		0,015		0,020	
Expanding market	0,587	***	0,811	**	0,331		0,873	
Plans and manages R&D	2,376	***	1,620	***	3,584	***	4,410	**
Technological cooperation	0,716	***	1,316	**	-0,203		-0,663	
Difficulty to finance innovation	0,007		0,541		-0,616		1,379	
Patents t-1	-0,001		0,133		1,453	***	0,107	
Exports technology	1,457	***	2,392	***	-1,257		2,992	*
Imports technology	-0,129		0,159		0,868		0,811	
<b>Log likelihood</b>	-401,6		-95144		-47966		-27954	
<b>Pseudo R<sup>2</sup></b>	0,3909		0,3534		0,6100		0,5550	
<b>Prob &gt; chi<sup>2</sup></b>	0,0000		0,0000		0,0000		0,0000	
<b>N</b>	1499		340		298		105	
<b>Correctly classified (%)</b>	86,99		87,65		93,62		86,67	

\* p < 0.05 \*\* p < 0.01 \*\*\* p < 0.001



**TABLE 2**  
**AVERAGE EFFECT OF NATIONAL INNOVATION SUBSIDIES ON THE**  
**FIRMS' R&D INTENSITY.**

	Non Subsidised Firms	Subsidised Firms	ATT-Effect	t-value Bootstrap
Spain	1267	250	1.846	5.874 (***) 5.805 (***)
Catalonia	288	55	2.507	3.915 (***) 3.988 (***)
Madrid	256	44	1.442	1.172 (*) 1.054
Basque Country	75	34	2.312	2.143 (**) 2.194 (**)

\* p &lt; 0.05

\*\* p &lt; 0.01

\*\*\* p &lt; 0.001

## APPENDIX TO ESTIMATE THE PS AND THE ATT.

The first step to evaluate the effect of a treatment is to calculate the propensity score (PS). The PS is defined as the conditional probability of receiving a treatment given a certain set of individual characteristics ( $X_i$ ). A lineal probability model can be used to estimate the PS. In this study we have applied a logit model due to its ease of use and its extended application in statistical analysis:

$$\Pr\{P_i = 1 \mid X_i\} = F(h(X_i)) \quad [3]$$

where  $F(\cdot)$  is the function of the normal distribution, or logistical cumulative, and  $h(X_i)$  is a function of covariants without lineal terms of higher order.

Once the PS is computed it is necessary to comply with a series of different assumptions, which constitute the basis to obtain non biased estimates of the average effect of a treatment on the treated:

### Assumption I.

A set of individual characteristics ( $X_i$ ) should be balanced. In this way, firms with the same propensity score value  $p(X_i)$  would have the same distribution of individual characteristics regardless of the programme participation status. Thus, the assignment to a treatment would be random between units (Becker and Ichino, 2002).

$$T \perp X \mid p(X_i) \quad [4]$$

### Assumption II.

A conditional Independence Assumption introduced by Rubin (1977) should be fulfilled, where it is assumed that the differences are captured in  $p(X_i)$  and the potential outcomes  $\{Y_0, Y_1\}$  are independent of the programme participation status.

$$Y_1, Y_0 \perp T \mid p(X_i) \quad [5]$$

Thus, the potential outcome of the non-treated units  $Y_0$  conditioned by  $p(X)$ , has the same distribution function as the potential outcome of the treated units  $Y_0$  in the case of not having received treatment. In other words, the counterfactual state estimated for units in receipt of treatment is the closest to that experienced in the case no treatment has been received.

### Assumption III.

The Stable Unit Treatment Value Assumption – SUTVA must be fulfilled, where the effect of the treatment on a given unit does not depend on the assignment to a treatment of other units. In other words, under this

assumption the result observed for a unit in receipt of treatment is dependent entirely on that unit (Rubin, 1978; Rosenbaum and Rubin, 1983; Angrist et al., 1996).

This condition is probably fulfilled in this study, given that the innovation effort of a firm depends largely on its individual effort. In the Spanish case, subsidies are low compared with private investment. It was verified that the mean size of aid of the firms of the sample was 7.1%<sup>7</sup>. Furthermore, the use made by firms of subsidies received differed according to individual needs, and its effect depended on its appropriate use and management. Nevertheless, this study includes all subsidy schemes currently in operation in Spain, which should reduce possible interference arising from firm participation in more than one programme. A review of the fulfilment of this condition in the case of innovation policy in Germany can be consulted in Almus and Czarnitzki (2003).

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<sup>7</sup> A figure which is very close to the Spanish mean of 7.2%, according to calculations made from data published by INE in “Estadísticas sobre Actividades de Investigación y Desarrollo Tecnológico 2001”. Size of subsidy = (quantity of subsidy/R&D expenditure).